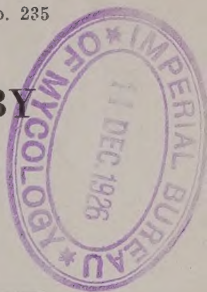


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Bulletin No. 235

CABBAGE YELLOWS, CAUSED BY *FUSARIUM CONGLUTINANS*, IN IOWA



A selected head of Iacope. This is the type which is considered desirable to fix in combination with high yellows resistance.

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

BOTANY AND PLANT PATHOLOGY
AND TRUCK CROPS SECTIONS
COOPERATING

AMES, IOWA

SUMMARY

Cabbage yellows caused by *Fusarium conglutinans* is widely distributed in Iowa. It probably was introduced into the state just previous to 1910 on cabbage transplants shipped from the southern states. The organism causing cabbage yellows is the chief limiting factor in cabbage production in the Muscatine Island section and contiguous territory on the Iowa side of the Mississippi River. The yellows organism may live in the soil for long periods of time, at least 11 years, and still be destructive to a cabbage crop. Cabbage, cauliflower, Chinese cabbage, kohlrabi and brussels sprouts are known to be hosts of this organism.

Cabbage yellows is most destructive in the Cornbelt states, where the temperature range is favorable for the causal agent during the growing season of the crop. Losses ranging from 50 to 95 percent of a crop are common on any of the commercial early or late varieties. Certain individual plants in the variety Copenhagen market have proved quite resistant.

Because the early sorts, such as Copenhagen market, mature in the early summer, and because of the unfavorable climatic influences for seed production in Iowa, a greenhouse method of selection for disease resistance and seed stock propagation was developed.

A cabbage yellows resistant strain has been selected out of the variety Copenhagen market by the greenhouse method. This strain is known as Iacope and resembles the parent variety, but is less uniform as to type and somewhat later than the earliest strains of Copenhagen market. It is well adapted to propagation on infested soil.

Seedbed selection for resistance and seed stock propagation in the greenhouse affords a practical method of securing desirable strains.

Its resistance varies, depending upon the degree of soil infestation with *Fusarium conglutinans* and weather conditions. Iacope has produced a marketable crop on badly infested land during the last two years, 1924 and 1925.

Continued selection thru four generations of Iacope in infested soil has increased its resistance. A trial in infested soil with the F_1 generation of 14 selfed strains showed that resistance was at least maintained in 13 of the 14 strains.

CABBAGE YELLOWS, CAUSED BY *FUSARIUM CONGLUTINANS*, IN IOWA

By I. E. Melhus, A. T. Erwin and Frank Van Haltern.

The disease known as cabbage yellows, caused by *Fusarium conglutinans* Wollenw., made it necessary to discontinue growing cabbage on Muscatine Island, and on much of the contiguous territory on the mainland. Cabbage yellows was first reported in Iowa in 1910 in the Muscatine Island section. At that time certain men there were growing large acreages of cabbage and the daily loading ranged from 50 to 75 cars during the shipping season. Cabbage had become a profitable commercial crop. The soil and climate were well suited to the production of an early cabbage, which found a ready market in the southern states.

Within three years, cabbage yellows, which had been introduced from the southern states on transplants, had spread thru the soil of all the fields and made cabbage growing on Muscatine Island a complete failure. Cabbage had to be replaced by less profitable crops. Since then, cabbage yellows has spread rapidly in Iowa, until the disease now exists in most of our market garden sections around our larger cities and towns. There is every indication that in a relatively short time all of the soils in the state suitable for growing cabbage will become infested and worthless for this crop, unless some method of control can be found.

A study of control measures, started in the spring of 1916, is still in progress. At the outset it became necessary to learn the distribution, destructiveness and relation of the disease to climatic conditions in Iowa. It was soon apparent that the most logical means of control involved the selection and development of disease resistant strains in the variety or varieties best adapted to our soil and climatic conditions. This bulletin records the results of these studies during the past eight years.

DISTRIBUTION AND PREVALENCE OF CABBAGE YELLOWS

Cabbage yellows is unknown outside of the United States. Jones, Walker and Tisdale (9) report that cabbage yellows is unknown in Denmark, Holland, Germany, Ireland, England, Norway and Japan. It is significant that this disease is unknown in the cabbage seed producing sections; namely, Denmark and Holland. Apparently it is limited to the United States, judging from present information as to its distribution.

Smith (19) first reported cabbage yellows in the United States. He found badly diseased cabbage fields near Albany, New York, in 1895. He also found the disease in a number of places in Maryland and thought that it probably was distributed in other parts of the United States. Orton (14) reported the disease from North Carolina and Maryland in 1901. Jones and Gilman (8) say that yellows was destructive in the Racine district of Wisconsin as early as 1900. Manns (11) says that growers reported cabbage yellows as destructive to cabbage in Ohio about 1905. In 1911 it was reported from 11 counties in that state. In 1912 Harter (7) isolated *Fusarium conglutinans* Wollenw. from infected material secured from North Carolina, South Carolina, Georgia, Mississippi, Maryland, Virginia, New York, Ohio, Wisconsin and Michigan.

Data concerning the early spread of cabbage yellows are scanty. However, records of the Plant Disease Survey, United States Department of Agriculture, show that the disease has been reported from 33 different states. In the survey reports one finds statements relative to yellows. In the southwest cabbage section of Virginia, in Wythe and Smythe Counties, where several thousand acres of cabbage are grown, the losses have been severe. In the district about Louisville, Kentucky, some fields showed losses of 30 to 75 percent in 1920.

The disease was first brought to the attention of station pathologists of Michigan in 1917, and in 1922 it was reported as being serious in the vicinity of Grand Rapids. It is the most serious cabbage disease in Indiana, having become a limiting factor in many cabbage growing districts of that state. In Illinois, yellows has invaded the Chicago market gardens. In 1922 it was reported severe in the market gardens about St. Louis, Missouri. In the districts about Mobile, Alabama, and Crystal Springs, Mississippi, yellows is quite general, but apparently is not so destructive as farther north.

It is very common in Tennessee, especially in Henderson, Scott and Davidson Counties. Kansas sustained losses of 10 to 50 percent in 1919, and in 1923 that station reported that yellows-free cabbage fields were difficult to find. In 1924 cabbage yellows was reported for the first time from California by Smith (20). In the states where the disease has been destructive for some years it is not confined to trucking sections, but has become generally distributed in smaller gardens.

Other states reporting cabbage yellows are: New Jersey, Pennsylvania, Delaware, Louisiana, Texas, Oklahoma, Minnesota, Arkansas, Georgia, West Virginia, Nebraska, Colorado, New Mexico, North Carolina, South Carolina, North Dakota and Mon-

tana. This indicates the general and widespread distribution of cabbage yellows.

It has not yet been reported from the New England states and the Northwest; it is not very destructive in New York state, nor in the northern parts of Wisconsin, Michigan and Minnesota. This appears to be due to the fact that in those sections the climate is cool during the early growing period when the cabbage plant is most susceptible to attack. In the far south winter is the growing season, so that here again the climate protects the crop. The disease is most destructive in that section of the United States where the temperature is high during the growing period of the cabbage crop. This includes the Cornbelt.

CABBAGE YELLOWS IN IOWA

The earliest information available as to the shipment of cabbage out of Iowa occurs in the report of the Iowa Agricultural Society for 1885 when 1,685 barrels were shipped from Muscatine County. The cabbage patches were mostly of three to five acre areas until 1893, when the Heinz Pickle Company set 15 acres to cabbage. As cabbage production increased, growers began to ship to the larger cities of the Middlewest. By 1905 there were 1800 acres grown on Muscatine Island alone. The period of greatest expansion of the cabbage industry was between 1905 and 1910. Individual growers increased their acreage until some growers produced from several hundred to 1,000 acres annually. H. E. Hahn, a commercial grower at Muscatine, Iowa, says that 750 to 1,000 cars were shipped annually from Muscatine alone.

In 1906, four of the largest growers on Muscatine Island, hoping to get on the market a little earlier, shipped a carload of plants up from South Carolina. On arrival, these were found to be infested by aphids and plant diseases which were not known by the growers, but the best plants were sorted out and planted. It was during the next two or three years when growers on the Island began to discover that their cabbage plants were dying of yellows, altho the nature of the disease was not recognized at that time.

In 1910 and the years following, the disease became so destructive on the Island that better than 90 percent of the plants in many fields died. By 1913 the cabbage industry on the Island was practically wiped out. Growers purchased or rented newer lands on the mainland, but as fast as the industry moved back from the river the disease moved with it. The yellows had become so generally distributed in the soil that it was difficult to raise or secure plants for field transplanting that were free from the disease.

Rummells (16), a commercial grower at Nichols, Iowa, 25 miles from Muscatine Island, says that cabbage yellows first appeared in one of his fields in 1913. The following year practically the whole crop of 200 acres was destroyed by yellows. In 1915 new land that had never produced cabbage was planted and yielded a fine crop, but when it was replanted in 1916 yellows appeared in several places. This field was then put in corn for two years before it was planted to cabbage again. That season yellows caused a total loss.

Shannon (18) of Nichols, estimated in 1922 that 32,082 acres in the Muscatine-Nichols district were infested with yellows. Besides the Muscatine district many fields are now infested in the trucking districts about our larger cities as Des Moines, Burlington, Davenport and others. Losses have been reported also from Red Oak, Ottumwa, Fort Dodge, Ames, Amana, Keystone, Belle Plaine, Carroll, Odebolt, Bluegrass and other places in Iowa. The known distribution indicates clearly that cabbage yellows is generally distributed in the state and that it is only a matter of time until all of our Iowa soils will be uniformly infested with this disease.

SYMPTOMS OF CABBAGE YELLOWS

IN THE FIELD

Cabbage yellows is caused by the fungus known as *Fusarium conglutinans* Wollenw. Once the soil of a field is infested the organism lives saprophytically in the soil from year to year and under favorable conditions attacks the roots of the cabbage crop, causing losses ranging from slight to 100 percent of the crop. (See fig. 1.)

In the field the symptoms are the progressive yellowing and then wilting and dropping of leaves, beginning with the lowest and continuing upward until only a few are left at the top of a long, bare stem. Eventually this stem also turns yellow, wilts and dies. (See fig. 2.) Where soil infestation is heavy and conditions are favorable, the majority of the plants may die in this manner. In other cases, yellowing and death may occur within a few days after the first external symptoms show. Again, the fungus may invade one side of the stem only, causing the plant to be deformed.

The disease seldom becomes serious in the field until the arrival of warm weather. At planting time the weather is usually cool and often quite wet. The fungus does not grow well at such low temperatures, while cabbage, being a cool weather crop, responds very well. In such cases the plants escape infection until the advent of hot weather, when the fungus is stimulated into



Fig. 1. A field of sixty acres of Copenhagen market grown near Muscatine in 1916. Ninety percent of the crop was destroyed by the cabbage yellows disease.

rapid growth. It enters the root hairs and passes up into the vascular system of the plant. In the course of a week or ten days the characteristic symptoms of the disease appear here and there over the field. If hot, dry weather continues, nearly every plant shows the disease.

Should cold, wet weather set in, the progress of the disease may be entirely arrested even in those plants showing early symptoms of the disease. With continued low temperature, a normal crop may be grown on badly infested soil, but such seasons are rare in the Cornbelt.

If a stem of a diseased plant is cut thru, a dark yellowish-brown ring will be plainly visible where the fungus has invaded the vascular system. Examined under the microscope, the vascular bundles will be found to contain the mycelium of the fungus. Often the disease may be diagnosed in the field by pulling off a yellowed leaf and looking for brown vascular bundles in the broken end of the petiole. However, leaves that are quite yellow may not show any darkening of the vascular bundles altho it may be quite evident in the stem. Vogel (23) made cultures from 45 diseased plants and succeeded in plating out *Fusarium conglutinans* from the stems of 43 of these, but only three of the plants yielded a culture of the organism from their leaf petioles. It is recognized that, as the plant gets older, the organism becomes general.



Fig. 2. Typical symptoms of the cabbage yellows disease. The leaves turn yellow and drop from the stem. The leaves dry up and disappear leaving the naked stem supporting a blighted, partially mature head.

IN THE SEEDBED

The most noticeable and characteristic appearance of yellows on seedlings is a bright yellowing, turning to gray as the leaf wilts. If the plants in the infested seedbed are kept cool and moist and are in good, rich soil, the disease may not show up to any great degree. This may lead the grower to think his plants are healthy and he may unwittingly spread infection to new fields by means of these plants. It is probable that the majority of fields are originally infested from such transplants. Very young seedlings are not attacked by the yellows organism. There follows a period of 12 to 14 days, often longer, after the seedling comes up when no sign of yellows can be found. To all appearances the plants are healthy. At this time the plants are establishing their root systems while depending partly on the food from the seeds. Apparently this length of time is required for the fungus to gain entrance into the root hairs and establish itself in the vascular system of the plant. At this time, if conditions are favorable for the causal agent, the symptoms of yellows begin to appear.

Figures 4 and 5 show seedlings at the stage when the disease is just beginning to appear. Often the cotyledons alone may become yellowed. These wither and fall while the remaining leaves appear healthy. Later the next lowest leaves may be dropped,

to be followed by other leaves in succession. These plants may survive long enough to carry the disease to the field. The leaves do not always show the bright yellow color, but instead may show only slight yellowing or only one side of the leaf may be yellowed and deformed.

The stem, which in a healthy seedling is plump and green, turns to a slate blue, becomes less turgid and finally dries up; the base of the stem is the last portion of the plant to shrivel.

RESPONSE OF THE CAUSAL ORGANISM

INFLUENCE OF ENVIRONMENTAL CONDITIONS

Fusarium conglutinans grows best at a comparatively high temperature. Gilman (4) failed to produce the disease in seedling cabbage plants grown in infected soil at temperatures ranging from 14° to 17° C., but secured a high percentage of diseased plants at soil temperatures of 17° to 22° C. (62.6° to 71.6° F.) and higher. Tisdale (21) found the temperature range of growth of *Fusarium conglutinans* on potato agar to be from 7° to 35° C., the optimum being 25° to 27° C. He also established 35° C. as the highest temperature at which he obtained diseased plants in infested soil. In our trials using Beijerinck's agar the fungus failed to grow below 11° or above 35° C. The optimum seemed to lie between 26° to 30° C. This organism is, generally speaking in the light of these results, one that is favored by a high temperature.

Below are given the mean monthly temperatures that prevailed during the six growing months for the years 1914 to 1923, inclusive, at Davenport as given by the Iowa Weather and Crop Service of the United States Weather Bureau:

Year	April	May	June	July	Aug.	Sept.
1914	50.0	64.3	72.4	78.6	75.0	66.4
1915	58.5	57.4	66.6	71.9	67.2	66.7
1916	49.4	61.3	65.8	82.6	76.9	64.0
1917	46.8	56.1	67.6	75.8	71.2	63.7
1918	45.6	66.2	70.2	74.1	76.8	58.9
1919	51.0	58.2	74.6	79.2	73.0	68.8
1920	44.0	60.5	72.3	73.4	72.6	68.8
1921	53.8	65.6	76.8	80.9	73.4	69.3
1922	50.9	66.0	73.4	74.2	75.3	68.9
1923	49.6	60.8	73.6	78.4	72.9	65.6
Normal	50.2	61.5	70.9	75.4	73.0	64.7

It will be seen that in none of these years did the mean for April reach Gilman's minimum (62.6° F.) for infection, altho the temperature on some days probably went above this point. However, since the soil warms slowly in early spring it is evident that little or no infection can occur in this month. The first yellows often makes its appearance in May, but is not very

destructive at this time. In 4 years of the 10, the mean for May went above the minimum for yellows infection, while in 3 others it came near to it. This means that many days of this month must have been warm enough for infection. In June, July, August and September the mean monthly temperature ranged above the minimum for infection during the whole 10 years with the exception of September, 1918, when the temperature went to 58.9°. The normal temperature for these six months indicates why the disease is so serious in midsummer and of little consequence in spring.

The mean temperature and average rainfall in Iowa for the four principal cabbage growing months during the 10 years ending with 1923 are given in the Iowa Weather and Crop Report as follows:

Month	Average temperatures	Average rainfall
	Fahrenheit	
May	60.2°	4.34 inches
June	69.9°	4.56 inches
July	74.9°	3.55 inches
August	71.6°	3.29 inches

If we examine these figures in the light of Gilman's results and our own, it will be seen that the average temperatures of June, July and August are very favorable to infection, while the temperature for May is slightly below that (62.6° F.) at which Gilman secured infection. This temperature range for May indicates clearly why the disease does not become destructive until June, when the crop is about two-thirds grown.

Tisdale (22) grew plants of cabbage under sterile conditions and inoculated the medium in which they were growing with *Fusarium conglutinans*. He found that the mycelium of the fungus entered the host thru the epidermis of the root hairs at any point. It grew directly thru the cells and spread upward to the larger roots, entering the vascular bundles.

Resistance of cabbage to yellows is only relative. With sufficient soil infestation and favorable weather conditions, any or all of the most resistant strains, so far developed, will succumb to this disease. Tests of our Iowa resistant strains show that in cool, wet seasons they may appear to be 100 percent resistant, while in hot, dry summers their resistance is seemingly appreciably lower. When making tests in winter for the elimination of susceptible strains, it was necessary to put the flats on the north side of the greenhouse above steam pipes in benches from which most of the soil had been removed so that the soil temperature registered between 20° and 25° C. On days when the greenhouse was cool, as on cloudy days, and the soil remained moist, there was a reduction in the number of plants that died

as compared to the number on sunny days. Tisdale (21) says that the Wisconsin Hollander should be resistant in any climate similar to that of Wisconsin, but that in a warmer climate it probably would not prove so resistant. This statement indicates clearly that in the late variety, Hollander, resistance is also only relative. Trials with this strain here in Iowa bear out Tisdale's statements.

The effect of the fungus on the host plant apparently is to inhibit the power of the host to collect and transport water from the soil to its leaves. This was apparent in experiments where cabbage plants were grown in yellows infested soil and the soil allowed to dry until the plants died of drouth. The healthy plants were able to draw water from the soil until only six percent was left in the soil. In the soil containing the diseased plants, however, there was 16.3 percent of moisture remaining, thus showing that the diseased plants were not able to exhaust the soil moisture to an extent equal to that of the healthy plants.

Melhus, Muncie and Ho (12) studied the rate of water flow thru stems of diseased and healthy cabbage plants by means of a fluometer. The average flow of water in five minutes thru 10 healthy stems having an average diameter of 15.6 mm. was 16.02 c.c., while the average for 10 diseased stems having a mean diameter of 15.5 mm. was only 1.86 c.c. in the same length of time. Evidently the organism causes some of the vessels to discontinue functioning. Just why they fail to transport water is not known, but studies made to date indicate that there is something other than mycelium in the ducts.

HOST PLANTS

Since *Fusarium conglutinans* may remain indefinitely in the soil, it is of interest to know if plants other than cabbage are hosts to this organism and if they may support the fungus in the absence of cabbage. Comparatively little has been done on this phase of the subject.

Gregory (6) says that the disease, cabbage yellows, is destructive to cauliflower, kale, turnip, kohlrabi, brussels sprouts, broccoli and collard altho he does not give the source of his data.

Dr. J. C. Gilman at the Iowa station, found *Fusarium conglutinans* causing a yellows disease on Chinese cabbage (*Brassica pekinensis*, Rupr.) in September, 1920. The Chinese cabbage was growing on soil which had previously produced a crop of cabbage that suffered seriously from the cabbage yellows disease. Other trials have shown that cauliflower, kohlrabi and brussels sprouts were susceptible; while radishes, kale, white and black mustard were not susceptible.

Enough has been done to indicate that *Fusarium conglutinans* is not limited to cabbage, but may attack several other cruciferous hosts.

A STUDY OF CONTROL MEASURES

It is well established that *Fusarium conglutinans* can live for a long time in the soil. Blackman Brothers of Nevada, Iowa, lost a crop on a piece of ground that had not been in cabbage for six years. Hahn Brothers of Muscatine sustained almost a complete loss due to yellows on a piece of ground that had not grown cabbage for 11 years. Jones and Gilman report a case where the fungus remained alive and destructive in land which had not grown cabbage for 14 years. Obviously crop rotation cannot be used to combat this disease.

In 1916 *Fusarium conglutinans* infested soil was treated in various ways. On one area lime was applied at the rate of 3 tons per acre; formaldehyde diluted 1 pint to 30 gallons of water was applied to another area at the rate of 1 gallon per square foot; complete fertilizer was used at the rate of 1 ton per acre on one plot and acid phosphate on another at the rate of 300 pounds per acre. None of the soil treatments showed any beneficial effect in controlling the disease. Steam sterilization, on the other hand, was effective, but quite impractical on a field basis. These results confirm earlier trials by Jones and Gilman indicating clearly the longevity of the organism in the soil and the difficulty of destroying it once it has become established.

TABLE I. TESTS OF CABBAGE IN FIELD SOIL INFESTED WITH *FUSARIUM CONGLUTINANS* DURING THE SEASON OF 1917 ON HAHN BROTHERS FARM AT MUSCATINE, IOWA

Cabbage	Date of setting	Total plants June 26*	Pct. healthy plants Aug. 14	Remarks
Copenhagen market	April 28	2138	5.5	
Jersey Wakefield	April 28	2235	10.5	Very early
Early summer	April 28	2026	10.2	
Flat Dutch	Apr. 28 & June 4	691	10.9	Very late
Fitch's strain, Succession	April 28	1488	11.4	Late
Fitch's strain, Copenhagen market	April 28	254	6.0	
Eureka	April 28	226	15.1	Late
Burpee's sure head	April 28	65	1.6	
Enkhuizen glory	April 28	523	4.3	
Hahn's strain Copenhagen market	April 28	259	56.8	Medium early
Wis. early resistant all season	June 4	50	96.0	Very late
Muscatine strain, Copenhagen market	June 4	78	70.6	Medium early
Wisconsin strain, Hollander	June 4	619	61.0	Poor type and late

*The number of plants was counted before the yellows disease manifested itself.



Fig. 3. The comparative resistance of different strains of the varieties Copenhagen market and Hollander growing in infested soil on the Hahn farm in 1917. The two rows next to the corn are Wisconsin resistant Hollander; the third row, one of the early resistant Copenhagen market selections and the next two rows were set with Commercial Copenhagen market.

COMPARATIVE TRIALS OF VARIETIES AND STRAINS

It was plain from our early experiments that crop rotation and soil treatment offered little hope and as a result efforts were directed toward finding either resistant varieties or strains of the variety, Copenhagen Market, the sort preferred by the growers in the Muscatine section. The variety tests as to resistance were started in 1917. Trials of new and reputed resistant strains obtained by the station and growers have been studied every year since with results quite like those shown in table I. This precludes relating in detail the specific cases encountered.

Summary of Table I. Plants of five early and two late varieties were grown on *Fusarium conglutinans* infested soil. At the same time six strains were also tested. These were selected because of their possible resistance to cabbage yellows. The two Fitch strains were selected by C. L. Fitch; one from the variety, Succession, and the other from the variety, Copenhagen market; the Hahn strain was selected by Henry Hahn of Muscatine from the variety, Copenhagen market; two Wisconsin strains were secured from the Wisconsin Experiment Station, and the Muscatine strain, Copenhagen market, was selected by the senior author at Muscatine in 1916.

The test shows that none of the five early sorts were very resistant. The variety Eureka was most resistant. Fifteen percent of the plants remained healthy. Copenhagen market was quite susceptible, only about five percent of the plants were free

from yellows. Among the strains, the Wisconsin early resistant All Season was most resistant, 96 percent of the 50 plants survived. Of the early strains the Muscatine strain of Copenhagen market proved most resistant. (See fig. 3.) It showed 70 percent resistance. This test demonstrated two points of much importance in planning subsequent work: (a) That varietal resistance among sorts that might serve to replace Copenhagen market was not very great, and (b) that it was possible to make selections in the variety Copenhagen market that carried marked resistance. The Wisconsin strain of Hollander was resistant, but unfortunately this is a very late variety, used chiefly for krout and winter cabbage. The Iowa growers are chiefly interested in growing an early variety, that can go on the market in June and July.

SELECTION OF RESISTANT STRAINS IN THE COPENHAGEN MARKET VARIETY

As stated earlier, the Muscatine section is best suited for growing an early variety that can be marketed late in June and early in July. The climatic conditions are such that this section cannot profitably grow the late varieties in competition with the more northern cabbage growing sections of Wisconsin and Michigan. As a result, the resistant strains of Hollander and All Season isolated by Jones could not be used. The only alternative was to isolate, if possible, resistant strains from some one of the early varieties, preferably the variety used by the growers in the section in question. That this was possible was first suggested by the results secured from selections made in 1916 and tested in 1917, shown in table I. Very recently Jones, Walker and Montieth (10) have also reported isolating resistant strains from some of the early varieties. They, however, have not advanced far with increasing their strains.

The early attempts to isolate resistant strains were based on the method utilized first by Orton (13) on cotton, Bolley (1) on flax and Jones and Gilman on cabbage. That strains carrying marked resistance could be secured in this way was easily demonstrated. The selection of resistant strains on a large scale, suited to commercial practice, proved very difficult with this early sort, however.

Iowa weather conditions necessitated making the selection of mother heads for seed production in early July and then holding them over until the next spring for seed production because the season in this latitude is too short to mature seed the same year. This made an unusually long storage period, necessitating expensive cold storage, and it also proved conducive to saprophytic and parasitic invasion of the heads by storage rot fungi and

parasitic organisms that by chance had been carried in with the stored heads. Late planting of early varieties is frequently not successful due to the hot, dry weather during July and August. It is difficult to secure a stand at this time and the plants that do grow seldom produce normal heads.

The difficulties confronted in seed production from the mother heads are well illustrated in the following experiences. In August, 1916, 81 heads were selected in a field of Copenhagen market on the Hahn Brothers farm at Muscatine, where there had been a 95 percent loss from cabbage yellows. These were placed in cold storage until October, when they were transplanted into the greenhouse. They set seed the following spring. Only 13 plants, however, survived and produced seed; the balance rotted either in storage or after they were set in the soil. Again in 1917, 2,000 mother heads were selected and placed in cold storage in August. They kept well until in January, when they began to turn black, lose their leaves and soften. At this time 200 of these heads were transplanted into the greenhouse, but only 6 plants survived. The other 1,800 mother heads were entirely destroyed early in February. The same year other heads were placed in caves, potato cellars and pits, but none of them were alive in the spring. Altho the authors have since annually attempted to store mother heads on a small scale and some growers have made similar attempts, few of the plants have survived the long storage period.



Fig. 4. The different selections are grown in duplicate series in "sick" soil in flats in comparison with a check, Commercial Copenhagen market. The soil and air temperature is made favorable for the organism. The degree of resistance is determined by a direct comparison with the check.

These, and many other experiences not cited, indicated clearly that the method of propagating seed from mother heads as described by Jones and Gilman, altho admirably suited for a winter variety and the Racine section, was not adaptable to an early sort and to the Cornbelt section where markedly different climatic conditions prevail.

ISOLATION OF RESISTANT STRAINS UNDER GREENHOUSE CONDITIONS

Having had little success in getting seed from mother heads held over from one season to the next, a new method of seed production was sought. This led to growing seed under greenhouse conditions from transplants that had been grown in yellows infested soil. The method has been briefly described by Gilman and Erwin (5). In other words, the plants were subjected to an epidemic of yellows in the seedling stage in the greenhouse flat comparable to that occurring in the field. The plants that survived were transplanted and became the mother heads for seed production. This is a modification of the method followed by Edgerton (2 and 3), who grew tomatoes in seedbeds infested by *Fusarium lycopersici* to eliminate susceptible plants before setting them in the field for crop production.

Seed is sown in flats containing *Fusarium* infested soil in the greenhouse in July where conditions are favorable as to sunlight, moisture and temperature, for the development of the yellows disease. The soil is kept moist, but not wet. The plants begin to show symptoms of yellows in two to three weeks after planting. As fast as the seedlings show yellows they are rogued out and a record is kept in order to determine the percentage of seedlings that die. The test is continued for three weeks after the plants begin to die and in this short time from 70 to 95 percent of the plants of commercial varieties commonly die. At the end of the selection period the remaining plants are taken out of the "sick" soil, potted in rich, "healthy" greenhouse soil under favorable conditions for growth.

That this seedbed test is effective in eliminating most of the susceptible plants is shown by the fact that often less than 10 percent of commercial strains remain at the end of the test. All the "F" strains shown in table III were obtained from a small lot of specially selected Copenhagen market seed secured from the Ferry Seed Company and selected by the seedbed method. Seed was grown from them in the greenhouse. In the column marked "index of resistance" it will be seen that many of the strains were three and four times as resistant as the parent, while 3F2-16 was 6.71 times as resistant. The method of securing these figures is explained in a later paragraph.

TABLE II. FIELD RESISTANCE OF STRAINS SELECTED IN THE GREENHOUSE

Cabbage	No. of plants	No. with yellows	Percent healthy	Index of resistance
1F2-10	47	10	79	464
2F2-8	38	11	71	417
Copenhagen market	43	40	17	100

Tests in the field have also supported the reliability of this method. In table II it will be seen that in the field, the difference between the resistant strains and the check was even greater than it was in the seedbed. In the seedbed the index of resistance of 1F2-10 was 338, while in the field it was 464. Similarly, the resistance of 2F2-8 was 312 in the seedbed and 417 in the field. These were the only strains that were tested in infested soil in the field in 1924.

It was found that plants set in the greenhouse in the fall would head, blossom and produce seed the following spring in April and May. The method and the different developmental stages are shown in figs. 1 to 4. By this method the acquiring of seed from selected mother heads became readily possible, altho quite costly and not suited to extensive seed production. However, it permitted the accumulation of large enough quantities of seed from each mother head to test adequately its response as to resistance and type in the field as well as maintain a small reserve for increase purposes.

By October or November the plants are of good size and are set 12 inches apart in a ground bed. As the heads begin to form plants of undesirable type are weeded out so that by the time heading is complete the remaining plants have more room. Because the plants are somewhat crowded in the bed, have a rich

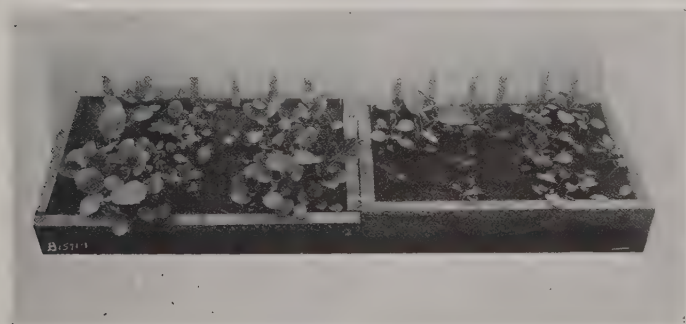


Fig. 5. The two flats with 10 different strains and a check in each flat show the relative resistance of different strains. The two check rows have only three plants remaining.



Fig. 6. These 8 plants are growing in a greenhouse ground bed and show the type and methods of propagation practiced in seed production.

soil and right conditions for vigorous growth, the heads tend to be slightly longer than when grown in the field where there is plenty of room.

The plants blossom in March. The greenhouse temperature is held between 50° and 60° F. The heads are formed in February, and without the intervention of a rest period, they burst and the flower stalk pushes upward. In May the seed begins to mature, and as it ripens the plants are cut off near the ground and put away to dry. The seed of each plant is saved separately and tested in the seedbed before being included in the lot to be used for increase.

In figs. 5 and 7 are shown cabbage plants growing in the greenhouse. Figure 6 shows the heads shortly before the flower stalks break thru. Figure 7 shows the plants in bloom and setting seed.

TESTING SELECTED STRAINS

After securing a number of resistant selections by the greenhouse method it is necessary to determine which of these have the best combination of resistance, type and earliness. They are first tested for resistance by comparing them in the seedbed, using checks of the parent variety from which they came. The strains showing the greatest resistance are then set in the field for a test as to type and other market characters.

In our work, flats were used, planting six rows crosswise with a check row in the center of each flat. Each strain was planted in two separate flats. In fig. 4 are shown some of the flats used for the tests. Here the plants are shown as they appeared at the beginning of the test before roguing was begun. It shows the approximate size of the seedlings when yellows becomes noticeable. In fig. 2 the same plants are shown as they appeared at the end of the test 26 days later. The seed was sown April 11, yellows appeared after 16 or 17 days and roguing was started May 5. The picture shown in fig. 1 was made May 4. The test ended May 31 and the picture in fig. 2 was taken June 4. The plants were much larger at the end of the test than at the beginning, but did not make as good growth as they would have made under more favorable conditions. In fig. 5, the third row from the right end of each flat is a check. There are only two plants left in one row and one in the other, while some of the strains showed many living plants, as shown in the flat on the left.

At the beginning of the test the plants in each row were counted, and as fast as they showed symptoms of yellows they were pulled and recorded. At the end of the test the percent living of each strain was determined. In order to correlate the results better in separate tests the percentages for the checks were arbitrarily raised to 100 and all other percentages raised in proportion. Thus, the strain I.5-23 had 62 percent living at the end of the test, while the check had 21 percent. If the check is now considered to be 100 percent, the strain I.5-23, figured proportionately, would be 2.95 percent. In other words, I.5-23 was 2.95 times as resistant as the check.

Having determined in the seedbed the comparative resistance of the several strains during the winter months, the higher testing strains were set in the field to study type characters, earliness and general desirability as market cabbage. Approximately 50 plants of each strain were set in the field. After the plants had become established, counts were made of the number of plants. At the end of the season the percentage of heading was determined. Earliness was estimated by the number of days from transplanting to the first formation of a firm head. Type was estimated on the basis of 10, using figures to correspond to desirability of type as follows: 1 to 2, very poor type; 3 to 4, poor type; 5 to 6, medium type; 7 to 8, good type; 9 to 10, extra good type.

Summary of Table III. In table III are given only those strains that tested high in the seedbed, and were later tried out under field conditions. In the seedbed tests resistance varied greatly ranging from 857 for I.5-11 down to 19 for I.5-5 (not given in the table). Altho I.5-11 showed the highest resistance in the seedbed, it proved to be of rather poor type in field trials.



Fig. 7. This shows the blossom stage of a crop of seed matured 1919. The plants were set in October, 1918, and the seed was harvested in May, 1919.

TABLE III. SHOWING THE COMPARATIVE RESISTANCE, TYPE, HEADING AND EARLINESS OF THE BEST SELECTED STRAINS

Strain	Index of resistance	Type	Percent heading	Average days to head
I.5-10	571	6		88
I.5-11	857	6		84
I.5-12	629	4		94
I.5-18	428	3		91
I.5-21	262	8		88
I.5-22	743	6		90
I.5-23	295	9		84
I.5-24	271	9		84
I.5-25	262	6		88
I.5-26	362	4		87
I.5-27	338	4		90
I.5-33	262	4		89
I.5-37	343	9		69
I.5-38	252	6		86
I.5-39	324	7		83
I.5-40	233	8		83
I.5-41	324	8		85
I.5-48	353	4		86
I.5-62	326	7	*48	62
I.5-67	313	9	58	81
I.5-68	330	6	81	74
I.5-69	248	4	18	84
I.5-70	257	7	100	63
IF2-3	294	8		85
IF2-10	388	4		93
IF2-31	274	6	72	82
IF2-32	304	6	54	75
2F2-8	312	6		86
2F2-20	226	4	44	94
2F2-24	304	8	85	81
2F2-25	230	5	53	83
2F2-29	243	9	100	66
16-6	305	8		86

*Half of this test was in poor soil and did not head.

Table III shows that both I.5-10 and I.5-11 were high in resistance, but lacked in type. I.5-12 was resistant but poor in type and rather late. I.5-18 was discarded because of poor type characteristics. I.5-21 was only fair on all points, while I.5-23 was extra good in type and rather low in resistance and earliness. The type of I.5-23 was such that further selections are being made from it. I.5-24 was also extra good in type but not quite as resistant and early as the preceding strain. I.5-37 was extra good in type, strong in resistance and comparatively early. This strain was one of the best. Two strains that were outstanding in earliness were I.5-62 and I.5-70, but they were only medium in type. The table shows I.5-62 as heading only 48 per cent. However, it happened that in the field half of the plants of this strain were in an outside row in very poor, hard soil. The only objection to this strain was its type. Another outstanding strain was 2F2-29, which was desirable in everything except resistance. It will be seen from the foregoing discussion that the major difficulty in selection is to secure all four desirable characteristics combined in a single strain.

HISTORY OF THE IACOPE STRAIN

Late in 1918, a number of Copenhagen market mother heads were selected out of a field of cabbage that had been practically destroyed by cabbage yellows at Bluegrass, Iowa, near Muscatine. The heads that were secured were not altogether desirable; some were bursting and others were infected with black rot, *Pseudomonas campestris* (Pam.) Erw. Smith, and black leg, *Phoma lingam* (Tode) Desm. Furthermore, most of the earliest plants had matured too far to be used for seed purposes. Some of these were shipped to W. A. Walker at Racine, Wisconsin, for storage and seed production. Six crates were shipped to Ames and immediately transplanted in the greenhouse. Twenty-one of these produced seed. Mr. Walker also grew some seed by the field method, which was returned to the Iowa Station the next summer. The main portion of the two lots of seed, about two pounds, was mixed and labelled I.5.

In a field test in 1921 at Muscatine, I.5, growing in infested soil, showed a resistance of 61 percent, where less than 1 percent of the commercial Copenhagen survived. This strain, both at Muscatine and Ames, was so much better than the other strains tested that a large amount of the greenhouse space was given over to it in the winter of 1921-22 for the production of seed. In May, 1922, enough seed was secured so that small lots were set aside for increase purposes. Some of this seed was sent, thru Hahn Brothers of Muscatine, Iowa, to Chas. H. Lilly Company at Seattle, Washington, to be increased. In the fall of 1923 the Lilly Company returned 25 pounds. Another small lot was sent at the same time to J. M. Lupton and Son of Long Island, New York, for increase. The latter firm returned 23 pounds of seed in the fall. I. H. Vogel of Lupton and Son Company sent the following report as to type and earliness of the plants he grew for seed in the fall of 1922:

Earliness	Type
8 percent matured in 79 days	61 percent of true Copenhagen type
73 percent matured in 103 days	30 percent slightly off type
	9 percent markedly off type

In the spring of 1922 small samples of Iacope seed were sent to 14 different growers and state experiment stations. The substance of the reports in the fall was that this strain was a little later than the parent variety, Copenhagen market, and less uniform in type, but that it was a great deal more resistant to cabbage yellows than the commercial varieties. This was quite as much as could be expected, considering that the mother heads had been selected late in the season after the earliest heads had either died or were too far advanced to be used for seed purposes.

TABLE IV. SHOWING THE RESULTS OF A COMPARATIVE TEST OF IACOPE AND COPENHAGEN MARKET ON INFESTED SOIL AT NEVADA, IOWA, IN 1924

Row no.	Name of cabbage	Total plants	Count of June 3		Date of harvest	No. of heads	Marketable heads	No. of pounds harvested	Average weight of heads
			Pl'ts with yellows	Healthy pl'ts					
3	Cop. mkt.	189	75	60	July 15	56	30		
4	Iacope	193	37	81	July 15	97	50		
2	Cop. mkt.	178	81	54	July 22	59	33	270	4.6
5	Iacope	193	34	82	July 22	118	61	436	3.7
1	Cop. mkt.	173	89	49	Aug. 14	37	21	201	5.4
6	Iacope	183	32	83	Aug. 14	83	45	567	6.8

The total Copenhagen market harvested from rows 1 and 2 was 471 lbs.
The total Iacope harvested from rows 5 and 6 was 1,003 pounds.

Tests made in the years following gave such good results that the I.5 was named Iacope, and the work of selection was centered on this strain.

RESPONSE OF IACOPE IN THE FIELD

TRIALS IN 1924

Comparative tests have been made between the Iacope strain and the ordinary commercial Copenhagen market on the farm of Blackman Brothers at Nevada and on Hahn Brothers' farm at Muscatine.

At Blackman Brothers, Nevada, Iowa. At Blackman's three rows of commercial Copenhagen market and three of Iacope, each approximately 300 feet long, were planted in the spring of 1924 in yellows infested but otherwise good cabbage soil.

Table IV shows that on July 3 the Iacope strain evidenced considerably more resistance than did the commercial strain. Usually a marked difference between resistant and non-resistant strains is not evident early in the season. At Blackman's many plants, while showing slight evidence of yellows, were sufficiently resistant to live thru the season and produce marketable heads. As the season advanced, a still greater number of the commercial strain plants went down, while relatively fewer of the Iacope strain became unmarketable.

One row of the commercial strain and one of the Iacope, rows 3 and 4, respectively, were harvested July 15. Rows 2 and 5 were cut July 22, and 1 and 6 on August 14. The comparative yields harvested July 15 from rows 3 and 4 are shown in fig. 8. The three crates on the right are Iacope, while the crate on the left is the check, Copenhagen market. The total number of pounds of Iacope harvested from two rows was 1,003, while two rows of commercial Copenhagen market yielded only 471 pounds. On an acre basis this yield would be 11 tons per acre for Iacope and 5 tons for the commercial Copenhagen, which is an increase of 6 tons to the acre due to the resistance of Iacope.

TABLE V. COMPARISON OF YELLOWS RESISTANCE OF FERRY'S COPENHAGEN MARKET AND IACOPE ON THE HAHN BROTHERS FARM AT MUSCATINE, 1924

Row no.	Cabbage	Total plants	Count July 1			Count July 20		
			No. healthy plants	No. plants with yellows	Percent healthy	No. healthy plants	No. plants with yellows	Percent healthy
1	Cop. mkt.	403	390	13	96			
2	Cop. mkt.	233	215	18	92			
3	Cop. mkt.	330	319	11	97	258	72	78
4	Iacope	306	305	1	100	270	36	88
5	Iacope	313	312	1	100	280	33	89
6	Iacope	305	304	1	100	284	21	93

The Iacope cabbage was from 10 days to 2 weeks later than the parent strain, had larger heads and produced correspondingly heavier. On July 22 the heads of Copenhagen market averaged 4.6 pounds each, while Iacope averaged 3.7 pounds. This is probably due to the later heading of Iacope, which had not yet arrived at the same stage of maturity reached by the commercial strain. However, by August 11 Iacope had had time to outstrip the other strain and its heads averaged 6.8 pounds, while those of Copenhagen market averaged only 5.4 pounds.

The quality of Iacope at Blackman's was fully as good as that of the commercial strain. In fact, no difference could be noted between the two in taste or crispness.

At Hahn Brothers, Muscatine, Iowa. In the spring of 1924 three rows of Iacope were grown in "sick" soil on the Hahn Brothers farm beside three rows of Ferry's strain of Copenhagen market*. Counts were made of the number of diseased and of healthy plants on July 1 and 20 as shown in table V.

Note that the percent of yellows had increased in both the Iacope and the Copenhagen market on July 20, but that the Copenhagen market showed a greater increase than did the Iacope. Later data were not obtained due to harvesting of the crop. It is quite probable that the difference would have increased.

The yields, as reported by H. E. Hahn, were 12.4 tons and 5.25 tons per acre for Iacope and Copenhagen market, respectively. This is an increase of 7.15 tons per acre in favor of the Iacope. This may be ascribed to the resistance of the Iacope strain, which enabled it to produce a crop, while the commercial strain went down badly with yellows.

Wisconsin Hollander was compared with Iacope in four alternating rows of the two varieties. The counts of diseased plants made on July 1, as shown in table VI, seem to indicate that Wisconsin Hollander is slightly more resistant than Iacope.

At Dreyer and Company, Kansas City, Kansas. A sample of Iacope seed and a small packet of one of the Iacope strains de-

*The Ferry strain was a specially early and good type head selection developed by Ferry Seed Co.

signated as I.5F2 were sent to Professor E. A. Stokdyk, extension plant pathologist at the Kansas Station, for trial. These were planted on the farm of Dreyer and Company near Kansas City in 1924. Professor Stokdyk very kindly supplied the results given in table VII.

The I.5F2 was reported as of fine type and heading practically as early as the commercial Copenhagen.

At Experimental Plots, Ames, Iowa. The amount of yellows infested ground available at the Experiment Station was limited so that only a few strains were tested in 1924. The results from these are shown in table VIII. The commercial Copenhagen market used as a check was bought of Alexander-Forbes and Company, Newark, New Jersey, as selected seed and was an excellent type of cabbage. It was only 17 percent resistant in the field, however. All the strains given in the table were, of course, among the better testing strains in seedbed tests. The seed for this test was sown in "healthy" soil so that there was no roguing before setting in the field. Among these strains of Iacope only one (I.5-37) proved to be of good market type. The others, while high in resistance, were of medium or poor type.

At J. W. Rummells, Nichols, Iowa. J. W. Rummells probably gave the Iacope strain its first extensive field test. He planted 60 acres on land where two cabbage crop failures had occurred due to cabbage yellows. Plants were grown in cold frames and set in the field rather late in May, 1924. Mr. Rummells (17) describes his results as follows: "We selected 60 acres of 100 percent 'yellows sick' land and by June first had the 60 acre field planted, using 10,000 plants for each acre, 600,000 plants for the 60 acres, and had enough plants left in the beds for 40 acres, showing the seed to have germinated practically 100 percent. After this cabbage had been cultivated and some hoeing done, we had an excessive amount of rain, the larger portion of the field was covered with water in some places to a depth of two feet. We dug ditches, which allowed the land to drain quickly, but it was wet and soggy for several days and the cabbage plants

TABLE VI. COMPARISON OF WISCONSIN HOLLANDER AND IACOPE

Row no.	Cabbage	Total no. plants	No. healthy plants	No. with yellows	Percent healthy
1	Iacope	413	367	46	89
2	Wisconsin Hollander	416	388	28	93
3	Iacope	413	358	57	86
4	Wisconsin Hollander	397	362	35	91

TABLE VII. SHOWING RESULTS OF TESTS OF IACOPE IN KANSAS

Cabbage	No. of plants	No. headed	No. with yellows	Percent yellowed
Copenhagen market (Com.)	99	28	54	54.5
Iacope	91	67	17	18.7
Iacope (I.5 F2)	113	101	5	4.4

TABLE VIII. SHOWING YELLOWS RESISTANCE OF SOME IACOPE STRAINS TESTED IN THE FIELD AT AMES IN 1924

Cabbage	Total plants	No. with yellows	Percent resistant
Commercial Copenhagen market	48	40	17
Iacope (I.5-26)	42	7	83
Iacope (I.5-27)	44	10	77
Iacope (I.5-33)	48	26	46
Iacope (I.5-37)	35	7	80
Iacope (IF2-10)	47	10	79
Iacope (2F2-8)	38	11	71
Iacope (I.5-25)	51	6	88

turned yellow, more so in the lower spots, and for a time it appeared that the entire crop would be a complete failure. The soil being rich and full of humus, the top dried off in a few days and we started to hoe and cultivate, working the soil as much as conditions would permit. The cabbage started to grow and in two weeks looked like a new field, green and healthy, and by July 20 the cabbage was properly matured to harvest. On the lowest, richest parts of the field, the type of heads was not as good as on the higher land containing a little sand and clay; these heads were all round, perfectly formed Copenhagen type, medium in size, and the entire field of excellent quality. This field averaged 10 tons per acre of good cabbage, first cutting, loaded on the cars. There were left in the field fully as much immature cabbage for a later cutting, which was done at different periods as late as November 1, showing this strain to be of excellent keeping qualities."

VARIATIONS IN STRAINS IN THE SEEDLING STAGE

Besides the variations in percent of resistance shown in the seedbed, other minor differences could be noted. Some strains gave large, vigorous plants, while others were quite small and delicate. The character of resistance also differed. In some strains the plant attacked by the yellows disease died quickly. In certain other strains nearly all plants appeared to be infected, tho they did not die immediately. Such plants gradually lost their lower leaves until most of them had only the topmost leaves left, altho the plants remained alive thru a large part of the test.

By a study of type in the seedling stage of cabbage plants, it is possible to select those that will prove of good type when mature. The Iacope strain (I.5-23) proved, in the summer of 1923, to be one of the best, as to type, that was grown in the field. Young plants of this strain are compact in appearance, with short, smooth-petioled, oval leaves that are rather light in color and have smooth, regular leaf margins. The leaf cluster is close to the ground. It is interesting to note a slight variation between two second generation strains of I.5-23, namely, I.5-23-2 and I.5-23-3. The strain I.5-23-3 varies from the other strain in having a longer stem and slightly coarser foliage. An-



Fig. 8. This is a field trial of Iacope in comparison with commercial Copenhagen on *Fusarium conglutinans* infested soil at Nevada, Iowa, in 1924. The yields were Copenhagen market, 5 tons, and Iacope, 11 tons per acre.

other strain, I.5-39-2, has a long stem and coarse wrinkled leaves. I.5F2, which has been tested by E. A. Stokdyk in Kansas and reported as a very desirable type, has a compact cluster, short stem, smooth oval leaves and short petioles. Knowing something of the desirable seedling characters, it is possible to eliminate many off-type plants and strains while making the selections for resistance in the greenhouse.

RESISTANCE THRU CONTINUED SELECTION

The greatest gain in resistance seems to be secured in the first selection. If this has been made under very severe conditions, one could hardly expect much improvement in further selections. However, all resistance selections so far made, whether of cabbage, tomatoes or other plants, appear to have a certain percentage of susceptibility. Whether this can be reduced remains to be demonstrated. Pritchard (15), in a limited test, failed to get increased resistance to wilt in tomatoes after the second generation. However, he says, "Whenever the real differences become small, as in the present case, they are obscured by fluctuations caused by environmental factors."

Jones and Gilman (8) found that the average resistance of all the second generation strains of cabbage was about equal to that

TABLE IX. RESULTS OF CONTINUED SELECTION FOR RESISTANCE

First generation			Second generation			Third generation			Fourth generation		
Strain	Percent resis- tance	Index of resis- tance	Strain	Percent resis- tance	Index of resis- tance	Strain	Percent resis- tance	Index of resis- tance	Strain	Percent resis- tance	Index of resis- tance
Iacope	38	206	I.5-23	45	145	I.5-23-1 I.5-23-2 I.5-23-3	75 85 81	264 304 289	I.5-23-1-1 I.5-23-2-C I.5-23-3-N1 I.5-23-3-N2 I.5-23-3-NC1 I.5-23-3-C	98 95 98 98 95 87	466 452 466 466 452 414
			I.5-39	62	200	I.5-39-1 I.5-39-2	68 81	243 289			
			I.5-8	66	213	I.5-8-1 I.5-8-2	68 78	243 279			
						I.5-8 I.5-8-4 I.5-8-5 I.5-8-6	80 73 78 79	286 261 279 282	I.5-8-2-1 I.5-8-2-2 I.5-8-3-1	89 93 80	424 443 381
Commercial Cop- enhagen market*	17	100		31	100		28	100	I.5-8-6-C	88	419
										21	100

*The same lot of seed of the check Copenhagen market was used in testing the response of the first three generations. The fourth generation check was a different lot of commercial Copenhagen market.

of the first generation, but that some strains were better than the parent, while others were poorer. Among our second generation strains, many went far above the first Iacope generations, while many others showed a susceptibility equal to that of the commercial Copenhagen market.

Of interest is a comparison of four generations of cabbage selection; the first selection was made in the field while the last three were made in the seedbed. These comprise all of the fourth generation so far tested.

The figures given in table IX seem to indicate that we can hope eventually to come near complete resistance. However, these results need to be verified in the field. It will be noted that the figures given for percentage and index of resistance, in the column marked "second generation," of I.5-23 and I.5-39 do not correspond with those given in table III. This is because the figures given in table IX were secured from a more recent test than were those in table III.

It will be noted that the resistance index of I.5-23 in the second generation is lower than that of the first generation. The resistance of the majority of the strains of the second generation went higher than that of the first. I.5-23 was kept because of its excellent type. The following generations show that the resistance has been increased, and in at least two or three of the fourth generation of this line the type has held up with that of I.5-23. The I.5-39 strain was discontinued because of its poor type.

RESULTS OF SELFING

In the spring of 1925, 14 strains were selfed, and a small quantity of seed secured from each. This seed was all planted in flats of diseased soil in the greenhouse, the plants being exposed to infection the usual length of time, three weeks after yellows showed, and then transplanted to pots. Table X shows the number of plants that grew and the percent that lived thru the test.

The most noticeable thing about these figures is that, with the exception of I.5F2-KS, the index of all the strains remained so uniformly high. Thus 19 plants grew from the seed of I.5-23-1-S and every one lived. Of the 13 plants of 2F2-29-S2 only one died and 35 out of 40 plants of I.5-23-2-S2 were resistant. The total number of plants of all strains was 1,039 and 78.8 percent survived the test. As compared with these strains, the check, commercial Copenhagen market, was only 22 percent resistant.

A DESCRIPTION OF IACOPE CABBAGE

Iacope is a strain of cabbage selected from the variety Copenhagen market for resistance to the cabbage yellows disease. Like its parent, it has a medium round, solid head, crisp, small core, and is of fine texture. The heads, altho larger, are less fixed as

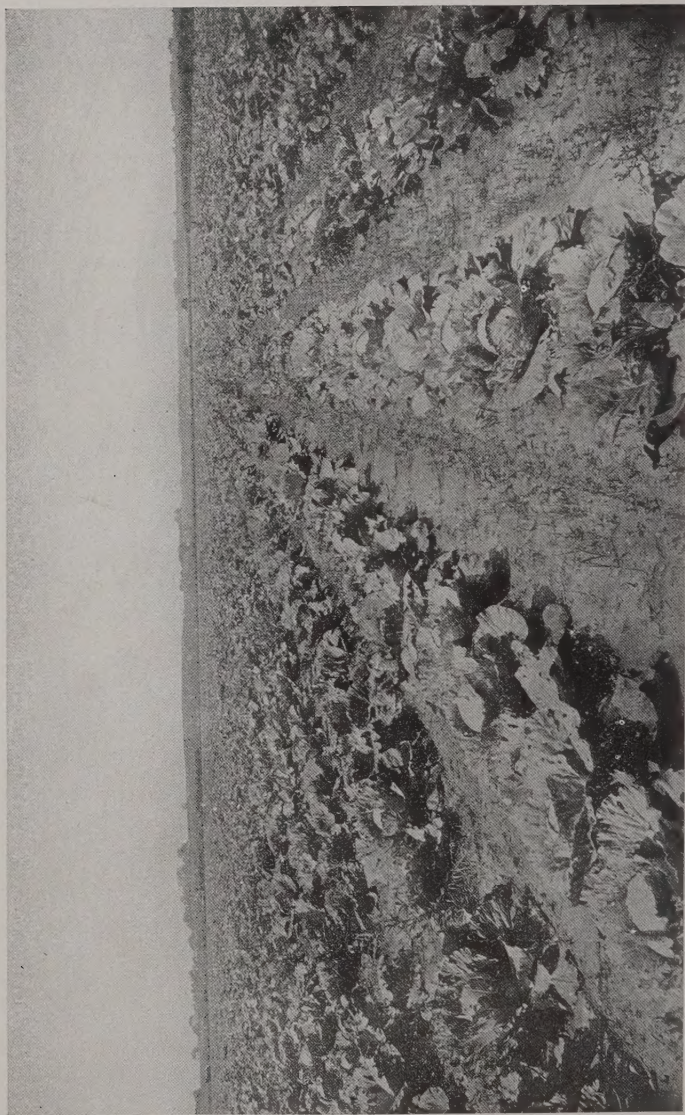


Fig. 9. A field of 60 acres of Iacope cabbage growing in infested soil on the J. W. Rummels farm, Nichols, Iowa. It yielded better than 10 tons per acre.

TABLE X. SHOWING THE RESPONSE OF SELFED STRAINS IN THE SEEDLING TEST

Strain	No. plants	Percent living	Index of resistance
I.5F2-KS	8	0	0
I.5F2-S2	240	78	355
I.5F2-S1	97	70	318
I.5-23-1-S	19	100	455
I.5-23-S2	106	86	391
I.5-23-S1	189	74	336
I.5-23-2-S2	40	88	100
I.5-23-2-S1	4	100	455
I.5-37-S	101	83	377
I.5-8-2-S	185	79	359
I.5-8-3-S	16	88	400
I.5-8-6-S	3	100	455
2F2-29-S2	13	92	418
2F2-29-S1	18	72	327
Total	1,039	78.8	358
Copenhagen market	223	22.0	100

to shape, color and time of maturity. (See fig. 10.) The time of heading is more variable. About 20 percent head as early as the earliest strains of Copenhagen market, while the other 80 percent head from 10 to 20 days later. This variation in time of heading is an advantage to the market gardener, but a disadvantage to the wholesale commercial grower. The foliage in general conforms to the type of Copenhagen market. However, there are many plants that are coarser and the foliage darker green. The stem is short with the head close to the ground.

The resistance to the cabbage yellows disease is not absolute. It varies from season to season, depending upon the degree of soil infestation and soil and air temperature. During the past two seasons, 1924 and 1925, more than 70 percent of the plants matured heads on land that was very severely infested with *Fusarium conglutinans*. In soil less severely infested, 90 percent matured.

The yield of Iacope is fully equal to, if not greater, than that of Copenhagen market. At Nevada in 1924 our test plot yielded at the rate of 11 tons to the acre, while at Muscatine, Hahn Brothers secured a yield of 12.4 tons.

Iacope is recommended where an early crop of cabbage is desired and for use only on land that is infested with the cabbage yellows organism. It is not immediately economical to grow Iacope on healthy soil.

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